

TITLE: Method for Assessing the Operation of a Conveying Apparatus

FIELD OF THE INVENTION

5       The present invention is directed to an apparatus and method for measuring the weight of material, such as rock, sand, gravel, earth, wood, grain, cement, etc., being processed by an apparatus such as a conveyor or bucket elevator system by an electric motor. In  
10      particular, the apparatus and method is directed to converting electrical power consumption of the electric motor powering the apparatus into weight per hour movement of raw material processed by the apparatus. The second part of this invention is using the tonnage rate  
15      measurements combined with a "no load" time as a new means of assessing daily production at each step in the process. Finally in a quarry or mine site where blasting of rock is used as a first step in breaking down rock for processing it is possible to use these tonnage rate  
20      readings if set up at several key steps in the crushing and screening process as a new method to evaluate blast fragmentation results.

BACKGROUND OF THE INVENTION

25      In many mining, quarrying, sand and gravel or pulp and paper operations it is desirable to measure the amount of raw material, such as aggregate, gravel, ore, pulp etc. being processed or moved, in order to maximize production at the operation. In the past, this has been  
30      accomplished either by weighing the amount of material loaded into transport vehicles, such as trucks or railway cars or through the use of auto weigh feeders, belt scales, or load cells all based on the use of strain gauge load cells combined with high speed sensors to

measure tonnage. This can be an expensive set up, requiring installation of new equipment, wiring and material testing for calibration for each piece of equipment to be monitored. To maintain accuracy the belt  
5 scales or load cells also require regular calibration and zeroing of cells.

In Automation Control the Belt Scale is the most widely used device to measure weight of material movement  
10 however these devices are installed as separate equipment on a conveying device. One example of such an apparatus, is the Siemens Milttronics MSI Single Idler conveyor belt scale with an Accumass BW100 Integrator. If a breakdown or error develops with the belt scale while  
15 the conveyor is operating then often the conveyor will continue to operate until a convenient time arrives to make a repair or adjustment with the scale with resulting loss of data.

20 There remains a need for a means of measuring the amount of material being processed or moved in an operation such as a quarrying or mining operation which is inexpensive, simple to setup and operate and to adapt to existing operations. There is also a need to know how  
25 efficient the operation is running i.e. each step in a quarry, mine or sand and gravel operation is designed to move a certain quantity of material daily at an hourly rate. At some steps in the operation, downtime may occur and if a record is measured of this downtime or "No-  
30 load", then this becomes an area that can be improved to increase production. Ideally an operator wants the process to run at design production rates with minimum downtime to maximize production. This invention will provide the measurement tools at a low cost to achieve

this goal. In addition if measurements are made at the conveyors coming off the primary and secondary crushers and at some key conveyors going to final stockpiles then these measurements can be used as a new method to compare  
5 blasting results.

The invention described herein is based on a new method to calibrate the device, which increases precision and includes new applications for the use of this device,  
10 which will help industry to become more productive. This invention is an improvement over an earlier application number JJ-11 384US(USA) and number JJ-384CA(Canada) by Steve McIassac who has worked with the current inventor to improve the accuracy and scope of this new invention  
15 over the earlier which focused on the lower cost version based on current readings. This invention is also an improvement over an earlier similar idea the KiloWate PT4 conveyor belt scale based on US patent 3,942,625.

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SUMMARY OF THE INVENTION

The present invention is directed to an apparatus and method for measuring the weight of material such as rock, earth, wood, pulp, grain, gravel, sand, ore, cement  
25 etc. being processed or moved by an apparatus such as a conveyor, apron conveyor or bucket elevator driven by an electrical motor. The apparatus comprises a means for measuring the electrical energy consumed by the motor powering the apparatus during operation of the apparatus  
30 and a calibration formula for converting the power consumption of the motor to tonnage per hour of raw material processed by the apparatus. A continual record is kept of all "No-load" and "start-up load" time during

the recording process and these figures are totalized along with tonnage for the recording period.

5        In an aspect of the invention, the apparatus is provided with a temperature sensor to monitor the ambient temperature and apply a temperature calibration factor to adjust the output of the apparatus based upon the ambient temperature.

10        In another aspect of the invention, the apparatus is provided with a belt speed sensor to monitor the speed of the belt and adjust the output should stalling or slippage of the belt occur.

15        In another aspect of the invention, the apparatus is provided with a digital inclinometer to monitor any changes in angle of a stacker conveyor to adjust the regression formula used in the conversion of kilowatt readings to tonnage by any change in angle of the  
20 conveyor as it moves up or down.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the present invention are shown in the drawings, wherein:

25        Figure 1 is a picture of a typical set-up in a quarry with a computer showing live the data being collected from the conveyor motor with also a Real-Time graph of data being displayed;

30        Figure 2 is a picture of the components making up the apparatus of the present invention using a watt transducer and current transducers for demonstration purposes;

Figure 3 is a picture showing the Tonnage Analyzer Instrument case with two Data Loggers and watt transducer installed;

5       Figure 3b is a picture showing a typical watt transducer installed for a conveyor motor Tonnage Analyzer. Also illustrated is a clamp AMPROBE CT installed for current tonnage conversion;

Figure 4 is a schematic drawing showing a typical layout of the components of the invention;

10      Figure 5 is a typical wiring diagram showing a watt transducer installation;

Figure 6 is a graph illustrating the method used to calibrate a typical conveyor belt with the resulting regression formula to convert amperes to tons (tonnes) 15 per hour for typical conveyor belt;

Figure 7 is a graph illustrating the method used to calibrate a typical conveyor belt with the resulting regression formula to convert kilowatts to tons (tonnes) per hour for typical conveyor belt;

20      Figure 8 is a table illustrating the correlation between the method of the present invention and actual measurement of tonnage recorded by a recently calibrated Techweigh Belt scale (Figure 1) of material processed in a typical quarry over several weeks of operation.

25      Measurements in kilowatts and amperes are converted to tonnage using the current invention-taking place with a single conveyor belt;

Figure 8b is a table illustrating the correlation between the method of the present invention and actual 30 measurement of tonnage recorded by a recently calibrated | Milltronics Belt scale\_with Accumass BW100 integrator of material processed in a typical quarry over several weeks of operation. This table illustrates the conversion of kilowatts to tonnes compared to the daily belt scale

readings. The No-Load and Start-Up load times that could be used to increase production are also illustrated;

Figure 9 is a typical graph of kilowatt readings from a motor being monitored;

5       Figure 10 is a summary of daily data from a conveyor motor showing converted kilowatt readings to tonnage compared to belt scale reading for the same conveyor. Also illustrated are the hours of lost production due to "No-load and start-up load" occurrences;

10      Figure 11 is a typical graph of ampere readings from a motor being monitored;

Figure 12 is a summary of daily data from a conveyor motor showing amp readings converted to tonnage compared to belt scale reading for same conveyor. Also shown are 15 the hours of lost production due to "No-load" "start-up load" occurrences;

Figure 13a is a typical Real Time graph showing tonnes/hr converted from a watt transducer and a graph of amps from the same conveyor motor showing the close 20 correlation in both systems;

Figure 13b is a typical Daily Tonnage summary using No-load adjustment.

Figure 13c is a typical Calibration Graph showing the calibration regression formula.

25      Figure 13d is a typical graph of kilowatts showing the effect of friction build up on a return portion of the conveyor causing a rise in No-Load readings and subsequent rise in kilowatt readings for the conveyor while loaded.

30      Figure 13e is the same graph as Figure 13d but enlarged to show the rise in No-load starting about 3:20pm from an average of 7.2kw to as high as 11.2kw around 3:45pm.

Figure 13f is a typical daily summary table showing the impact of No-Load adjustment during rapid rise in no-load readings seen in Figure 13e.

Figure 14 is a graph showing typical power  
5 consumption in kilowatts of a primary crusher;

Figure 15 is a spread sheet showing that average kilowatts used by a crusher during a typical days operation including "No-load" time or lost production.

Figure 16 is a spread sheet showing a summary of  
10 daily data from a conveyor motor showing converted kilowatt readings to tonnage compared to belt scale reading for the same conveyor. Also illustrated are the hours of lost production due to "No load and start-up load" occurrences. There is an illustration on the effect  
15 of cold temperature and the use of additional calibration formulas to adjust conversion of kilowatts to tonnage as temperatures fall.

Figure 16a is an example of a Greymont digital temperature sensor used to measure the ambient  
20 temperature during winter operation.

Figure 17 is an example of the Real Time Program showing actual readings from the data logger being recorded and converted to tonnes/hour and total tonnage. Also included in this program is a No-Load test to re-  
25 check the No-Load setting for the conveyor or bucket elevator. A No-Load test was just run on channel 1 as indicated by the red lines. Note this screen shot is similar on a standard computer screen or on a Touch Screen Industrial PC.

30 Figure 18 is an example of the AUTOMAT program screen shot that shows actual readings from the watt transducers at 1 second intervals converted to tonnes / hour and totalized for the day and year for 2 conveyors

being monitored. All information can also be displayed graphically.

Figure 19 is an example of an Automat program  
5 display showing the Automat version of the Glowe-Tech  
Tonnage analyzer with the Zero test page. This page  
allows the operator to run a manual zero test or the  
Automat can schedule the test daily at a specified time.

Figure 20 is an example of an Automat program  
10 showing the Glowe-tech Tonnage Analyzer with the Material  
Test and input data saving option used by the operator to  
calibrate the program.

Figure 21 is an example of the most recent version  
showing the use of a PDA or Pocket PC (iPAQ3850) with an  
15 Analog Data Logger collecting data live from a watt  
transducer in 1 second intervals.

Figure 22 the data is then converted to tonnage and  
displayed on the PDA for up to 8 channels of input data.

Figure 23 shows the PDA with the Zero test activated  
20 to automatically re-confirm the new no-load reading for  
the device being monitored.

Figure 24 the new no-load reading will be used to  
automatically re-calibrate the conversion formula  
insuring any changes in mechanical operation are filtered  
25 out of any tonnage conversion calculations.

Figure 25 is a typical Daily summary report for  
production time and tonnage for each device monitored

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

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The present invention is directed to a method for  
measuring the weight of material, such as rock, sand,  
gravel, earth, wood, grain, cement, etc., being processed  
by an apparatus such as a conveyor or bucket elevator

system driven by an electric motor. In particular, the method is directed to converting electrical power consumption of the electric motor driving the apparatus into weight per hour movement of raw material processed 5 by the apparatus. The second part of this invention is using the tonnage rate measurements combined with a "No-load" time as a new means of assessing daily production at each step in the process. Finally in a quarry or mine site where blasting of rock is used as a first step in 10 breaking down rock for processing it is possible to use these tonnage rate readings if set up at several key steps in the crushing and screening process as a new method to evaluate blast fragmentation results.

15       With the use of the device described in this invention the readings come from the motor operating the conveying device and should any failure or problem develop with the motor or conveying device then the system, if shut down for repairs, will also stop 20 recording data at the same time, hence no loss of data. For areas of a process where belt scales are installed and provide key information for batch processing, then the new apparatus in this invention could be installed at a low cost as a parallel system integrated with the 25 integrator of the belt scale to provide an early warning system of any errors or deviation in readings above a specified acceptable error range.

Using this invention provides a new approach to 30 automation control in mines, quarries and pulp and paper operations where this system may operate in parallel with existing systems thereby insuring no loss of data should an error or breakdown of a currently used belt scale occur.

The other important function of this invention is the continual recording of any "No load" times as well as "over load or start-up load" times. All of these times 5 represent lost production and can also lead to early failure of motors if the "start-up load" time occurrences become too frequent and occur with a conveyor loaded i.e. a conveyor motor will require a large power surge to start operating if the conveyor is fully loaded. This 10 surge can result in increased billing if monthly rates are based on peaks and these start-up surges will shorten the life of large industrial electric motors.

By using an ambient temperature sensor and speed 15 sensor this invention can also improve accuracy of conversion of readings to tonnage by compensating for cold weather effects. As temperatures fall below 0 degrees Celcius there is an increase in no-load power consumption and under cold and snowy conditions slippage 20 of the conveyor can occur.

A preferred embodiment of an apparatus according to the present invention is illustrated by the pictures in figure 1, 2 and 3 and the schematic drawing, figure 4. 25 The apparatus is used with a conveyor system which has a motor 13 which is used to drive a conveyor belt system 12. The motor 13 is electrically powered with the electrical power being provided by wires 11, connected to a suitable source of electrical energy such as the local 30 electrical grid or a local generator. As the conveyor motor 13 operates to drive the conveyor system 12 it draws the required electrical energy from the electrical power source. The amount of electrical energy drawn by the motor 13 is related to the load placed upon the motor

13 which in turn is related to the weight of material on  
the conveyor system 12.

In order to measure the amount of electrical energy  
5 being drawn by the motor 13, a suitable means for  
measuring the power consumption of the motor is utilized.  
To obtain an actual measurement of the power consumption  
a watt transducer measuring device as seen in figure 3,  
is connected to the motor as shown in the typical wiring  
10 diagram Figure 5. In some applications if less precision  
(+/- 3%) is acceptable it was found that using a current  
Transducer (CT) (Figure 2, item 4 or 5) to measure the  
current passing through one of the line wires supplying  
power to the conveyor motor, provided a close correlation  
15 to watts being consumed with commercial grid  
installation. This means for measuring the electrical  
energy may be hardwired into the system by being  
connected in series or parallel with the motor 13  
depending upon whether the current or kilowatts are being  
20 measured. Preferably, in order to easily adapt the  
apparatus of the present invention to existing mining,  
quarry, cement or pulp and paper operations, the  
measuring device is selected so that it can be easily  
wired into the power distribution panel for the motor  
25 operating the conveyor, apron conveyor or bucket  
elevator. For the watt transducer direct connection to  
Line 1(R), 2(S) and 3(T) for voltage input and Current  
transducers are attached to line 1(R) and 3(T) using  
split core or donut style CT's (instrument grade quality  
30 to insure accuracy of readings). One example of a watt  
transducer used is a GMI watt transducer with donut style  
CT's (figure 2).

For current applications either clamped or split core transducers are attached to one of the line wires, figure 3b, item 4 for the conveyor motor and provide an indication of the current passing through the wire. One 5 example of such a device is an AMPROBE current clamp 4 or a GREYSTONE Split Core Current Transducer 5.

The output of the measuring device whether it is a watt transducer or current transducer 4, 5 or 6 are 10 connected to a suitable recording device such as an ACR Smart Reader Plus 3 or Plus 7 data loggers 7 or a programmable logic controller (PLC) 14 which records and stores the electrical readings. The data from the data logger 7 or PLC 14 is passed to a suitable computer 9 or 15 SCADA 15 which converts using calibration formulas the electrical readings recorded by the data logger 7 into tonnage per hour of material passing over the conveyor system 12. This information may be provided on a live basis using Real Time software (as supplied by ACR) or 20 Dynamic Data Exchange (DDE) transfer of data to a central computer 15 spread sheet, via modem or direct connection using a RS235 cable 8 or hard wired directly to a PLC 7.

For set ups where weight measurements are to be 25 incorporated as part of automation controls, the output signal from the watt transducer (highest accuracy) in a 0-5 volt or 4-20 ma format can be fed to a programmable logic controller (PLC), item 14 for conversion to tonnage and relayed to a SCADA or central computer 15 for 30 totalizing or operation of other equipment.

Under cold weather conditions, ie below 0°C, the use of an ambient temperature sensor such as a GREYSTONE TE500 outside temperature sensor Figure 16a, item 16 can

be used to record temperature to adjust kilowatt conversion to tonnage as shown in Figure 16. The 4-20 ma output from this sensor can be relayed to the data logger 7 or PLC 14. Under cold weather conditions if slippage of 5 the conveyor is a possibility then the use of a speed sensor such as a SIEMENS MILLTRONICS Return Belt Speed Sensor (RBSS), Item 17 can be used to measure the change in speed of the conveyor by the change in pulse output from this sensor. This pulse signal from belt speed 10 sensor 17, can be sent to the PLC 14 for recording and by integration the change in speed can be used to adjust the converted tonnage.

The present invention is based on the measurement of 15 electrical energy supplied to an electrical motor driving a processing apparatus such as a conveyor, apron conveyor or bucket elevator system either by the utility power grid or a generator. The electrical energy supplied by the utility power grid is normally well-balanced in the 20 three phases allowing the system of the present invention to measure the kilowatts or simply the current component on one wire feeding the motor to determine the tonnage per hour for a pre-selected interval. The typical 25 electrical motor operating a piece of equipment such as a conveyor, apron conveyor or bucket elevator system in a mine, quarry, cement plant, sand and gravel or pulp and paper plant will consume a certain amount of electrical energy for a short period after start-up to initially turn over the motor- "Start-up load". A second level of 30 power consumption is reached to operate a piece of equipment in an idle manner with no load of material applied to the equipment- "no load". If the equipment settings are kept the same i.e. the angle of the conveyor, length of the conveyor, size, speed, no mud

build-up etc. or in the case of a bucket elevator if settings are kept the same, then once the load is applied, the additional power consumed to move or crush the material is directly proportional to the weight of  
5 the load so long as at least a minimum load of about 10 percent of the total load is applied on the equipment. As mentioned above, under cold weather, temperatures below 0°C will begin to effect the results requiring additional calibrations tests below this target to adjust for this  
10 effect, figure 16. In cold weather, slippage can occur, resulting in a change in speed of a conveyor, however with a speed sensor, this change in speed can be recorded and, by integration, the tonnage figures can be adjusted. One of the keys to this invention is the calibration  
15 graph (Figure 6 & figure 7) developed which clearly shows a linear relationship once a small load has been applied. However, this line does not intersect the "X" axis at the No-load setting if projected downward, i.e. it always intersects at a point lower than the No-load setting if  
20 projected to this "X" axis.

The electrical consumption of the power is measured as kilowatts or electrical current in amperes measured over short intervals between 1 and 8 seconds (the faster  
25 sampling rate increases accuracy) per reading and provided to the recording device such as the data logger item 7 to record and store the readings or a PLC item 14. Once several different loads have been timed accurately for a particular piece of equipment, the proper formula  
30 for the factors necessary to convert power consumption in kilowatts or electrical current amps to tons per hour for a piece of equipment may be determined as shown in figure 6, figure 7 and figure 13c. Once this formula has been determined, any subsequent readings from the equipment

may be easily converted into tonnage per hour utilizing the formula. Periodically (once per month or more frequently if desired) additional material or belt cut loading rates can be taken to confirm the regression 5 formula. Experience has shown that accuracy improves with actual material load tests and, if more than the recommended three tests are made, a better regression formula will result. Results will further improve if real time graphing is operational to check that material tests 10 are made while at stable loading rates on the conveyor, apron conveyor or bucket elevator. As with belt scales, it is recommended that the No-load setting be checked daily after equipment has had a chance to warm up. This procedure can also help to provide early warning of 15 possible equipment failure should a significant change in "No-load" figures be detected (figure 10 and figure 12).

The system of the present invention as described above was applied to conveyor systems in a variety of 20 quarry operations. The watt transducer and current transducer measuring devices were attached to the three wires of the three-phase electrical input to the motor driving a conveyor belt of the quarry system. This motor was fed by the local utility grid. The output of the 25 watt transducer and current measuring devices were connected to the input of a Tonnage Analyzer data logger | which measure kilowatts, AC current, pressure and temperature (Figure 3 capable of monitoring 14 conveyors or bucket elevators and expandable up to 42 input 30 signals).

The output from the data logger, item 7 was connected to a suitable computer, item 9 utilizing a standard interface port such as RS 232, item 8, USB and

DDE. The measurements for tonnage per hour were calculated using a regression analysis function in a suitable computer spreadsheet. The calibration of this system is illustrated in figure 6, figure 7 and figure 5 13c which is a graph of the amperage or power consumption of the motor vs. tonnage per hour of the conveyor belt system. As can be seen from figure 6, the motor in a no-load situation draws approximately 20.4 amps and in figure 7 which shows the calibration graph for kilowatts 10 to Tonnage the "no load" reading is 12.5 kwatts. As the load on the motor or the amount of material applied to the conveyor system is increased, the amount of amps or kilowatts drawn by the motor increases gradually until the load on the motor is sufficient to provide a linear 15 relationship between power consumption and tonnage per hour on the conveyor. Typically this will be on the order of 10 percent of the rated capacity of the conveyor system and well below the normal operating parameters of the system. From the data measurements as shown on 20 figure 6, 7 and 13c the regression analysis formula for this particular setup was calculated. A number of test runs were then conducted in which known loads of material were placed on the conveyor system and the predicted tonnage per hour output based on the regression analysis 25 formula compared to the actual tonnage per hour of the samples. The results of this are shown in figures 6, 7 and 13c. As clearly seen in figure 10, there is an excellent correlation between the predicted and actual tonnage per hour for this system using kilowatt 30 measurements. Figure 9 shows the graph of actual kilowatt consumption for a typical day. It is the actual readings taken from this graph which forms the basis for the conversion to tonnage as shown in figure 10. As an option, once the calibration formula has been established

as shown in figure 7, then the graph in figure 9 can be set up to show live tonnage readings as shown in Figure 13.

5       The same procedure applies to amperage conversion as shown in figure 11, showing a typical Amperage graph and figure 12 shows the spread sheet converting readings to Tonnage. In Figures 8 and 8b we have tables showing the summary of several days of data collection and results  
10      compared to belt scale readings for the same days. In figure 8 we show the comparison between readings taken with amperage versus kilowatts converted to tonnes. In figure 8b we show the conversion using kilowatts as well as the 'No-Load and Start-Up load' times which  
15      illustrates the potential for production improvement if these times could be reduced.

The whole system has also been set up with all outputs from transducers fed directly to a PLC at 1  
20      second intervals with all readings being processed directly on the Automat showing kilowatt readings and converted tonnage per hour rates and totalized tonnage as seen in Figure 18.

25       If the electrical power is supplied by a generator and the power is not well balanced then only the watt transducer method is recommended as the most accurate measurement of the power consumed to relate to tonnage per interval of time. In each case it is necessary to  
30      isolate the readings of electrical power in kilowatts or current in amperes which correspond to a "No-load" situation on the equipment to ensure that the cumulative data per period of time only includes readings when the equipment is running loaded. In the Real Time or Automat

program there is a separate No-Load test that can be run which takes the average of readings recorded while the conveyor or bucket elevator is run empty and we add 1.5 to 2.0 Standard deviations to the average to calculate  
5 the No-Load reading, Figure 13b. Likewise if frequent stop-start cycles occur especially with loaded equipment then these overload readings "Start-up surges" need to be isolated and recorded separately, to ensure daily power consumed as related to tonnage is only applied to  
10 readings were there is an actual material load on the equipment

It is very important to note that an essential feature of this aspect of the invention is the recording  
15 of these separate readings ie "No-load" and "start-up surges" which provide valuable information on lost productivity which can lead to large opportunities for improvement. In the case of "Start-up surges", this invention could help to extend the normal operating life  
20 of the conveyor motor by providing a record of these occurrences. If they became too frequent then ways could then be found to reduce these start-up surges with the additional benefit of increased production.

25 While the above example is described in connection with a conveyor system in a quarry operation, the present invention is not so limited. In addition to quarry or mine operations, conveyor systems, apron conveyors and bucket elevators in many processing industries such as  
30 cement plants, pulp and paper mills and processing plants for grain and other food stuffs, sand and gravel pits, etc. can also use the apparatus and method of the present invention.

It should also be noted that in the portable format using the data logger, the same system can be applied to a portable crushing plant with motors operated by hydraulic systems. Instead of using a watt transducer, a 5 pressure transducer can be used with the ACR SmartReader Plus 7 model and the same procedure described for watts can be applied to the pressure sensing device measuring psi used by the motor at various operating levels.

10       A further aspect of this invention is the use of this invention on a stacker conveyor. On a Stack conveyor, if they move up or down we need to add a further measuring device to input the angle of operation i.e. as the conveyor moves upward there is an added force 15 added to the components being measured. This may be achieved using a digital inclinometer, item 18 such as a US Digital A21 or an Xbow Tilt Sensor model CXTA01 with RS235 outputs. With either of these angle measuring devices, a signal can be fed to a PLC to provide data on 20 the angle above horizontal the conveyor is operating. The calibration process described above is repeated for differing loads at a minimum and maximum angle of operation. A new regression formula is calculated for each change in angle and as the conveyor moves upward or 25 downward the tonnage moved will be adjusted accordingly.

With the watt transducer model another aspect of this invention is the new ability to predict the maximum full load capacity for each conveyor or bucket elevator 30 based on the motor's specification and the corresponding tonnage per hour reading possible when the motor is operated at its maximum designed kilowatt rating. In other words, once the calibration formula has been established, then the maximum kilowatt rating of the

conveyor or bucket elevator motor can provide a direct conversion to tonnage the motor can be expected to move at that kilowatt reading.

5       A further aspect of this invention is the use of the output signal from the watt or current transducer as an input signal for automated systems to help adjust feed rates by feeders to a crusher. If the feed rate is too high, then presently available automated system may shut  
10 down a conveyor feeding a crusher rather than just adjusting the feed rate to provide a continuous flow to the crusher. In the case of a cone crusher, the best results will occur if the crusher is kept full all the time and no start and stops occur. Fewer start and stop  
15 occurrences which will increase motor life, improve accuracy of tonnage readings and result in higher quality crushing of rock.

The present invention is applicable to any operation  
20 where an apparatus or machinery is powered by an electrical motor and where it is desired to measure the tonnage output of the machinery such as a bucket elevator, apron conveyor or stacker conveyor. Another important application of this invention is to set up this  
25 system in parallel to an existing belt scale application as a low cost method of cross checking the tonnage readings being recorded by the belt scale. Belt scales can lose accuracy if a rock falls on the frame or material builds up around the frame or the idlers become misaligned etc. In modern quarry and mine sites where  
30 belt scale readings become the input data for automation control setups, a means to insure accurate data is being continuously provided is more critical and the present invention, if installed in parallel, provides an early

warning of any deviation in readings, avoiding errors in batch and blending processes. The apparatus and method of the present invention may also be used as the primary system providing a lower cost and maintenance free system  
5 for accurate measurement of tonnage of material.

The apparatus and method of the present invention provides an improved and faster method of measuring weight in tons (tonnes) of material over a device or moved by a piece of equipment at lower cost and with the capability of showing these tonnage reports locally or by telecommunications device to a remote location. This method may be applied at several locations in an operation and will provide a new way to measure tonnage  
10 and productivity through out the operation.  
15

Finally as mentioned at the beginning, this invention provides a new simplified method to compare blast fragmentation results. In the Mining and Quarrying Industries today all operators have a common goal to increase productivity and lower overall operating costs.  
20 Often it is easier to measure a localized improvement, which sometimes can actually increase overall costs and lower production rates at other parts of an operation.  
25 What complicates this process is the multitude of variables that occur in the transformation of solid rock to a final rock size or series of sizes and shapes with the least amount of waste. To further complicate the overall picture is the ever-changing choice of products  
30 and equipment advertised by manufacturers as ways to lower costs and improve production. One of the greatest challenges facing operators is finding ways to easily measure productivity improvements at each step in an operation to insure overall reduction in operating costs.

In industry today beginning with drilling and blasting there are many methods currently used to measure and compare results such as digital photo analysis of blasted rock fragmentation, actual sieve analysis, time studies to excavate a blast, just to mention a few. These methods will give good results for parts of a blast but not the entire blast and they are fairly complicated to use. Then there are the variables of actual geology at the site, which can vary from one location to the next. When you get to the crushing and screening of the rock, a whole new series of variables can influence the results such as choice of crusher, actual settings of crushers and screens which will alter the results as the rock is processed. With all these variables it will always be difficult to find a method which gives an actual overall comparison of results. However with today's technology and computer assisted measuring devices it is possible to build a model, which gives a much clearer picture on the actual energy consumption and production rates at each key step in the operation. Using this approach it has been found that such a model can be used to compare results of blasts and get a good correlation at the primary and secondary crushers to compare production rates and final split in low end and high quality crushed rock products.

In the simplest terms the process described herein is a new way to achieve this overall goal of reducing costs by comparing measurements of energy costs for explosives with energy consumption in kilowatts to operate equipment to process the rock. These measurements when taken at key steps in the operation combined with

production rates will give a surprisingly clear picture of the overall productivity and total operating costs.

In the case of mining and quarrying, where drilling and blasting are the first stage in the process to break rock for further processing, there is a need for a low cost and fast method to optimize results from drilling and blasting to maximize production in the crushing and screening stages in the operation. To do this a new process has been developed using the apparatus of the present invention, figure 2 and 22.

The apparatus of the present invention with its multi channel data logger is a new computerized process to measure tonnage and productivity in a Mine, Quarry or Sand pit operation combining several measuring device readings to establish a base line. This multi-functional process uses power or pressure transducers to input information from motors if data from belt scales or motor metering devices is not already available. With this process it is now possible to combine live conveyor tonnage productivity at key steps in the operation, with live power consumption readings at the Primary and Secondary Crushers using watt transducers. These measurements can then be used to compare individual blasts to optimize blasting results thereby achieving improved production at the primary and secondary crushing and screening stages of the mine or quarry. In other words, changes made at the drilling and blasting stage can be evaluated by comparing production rates with actual tonnages of final rock products produced versus percentage of lower end products such as fines or pit run materials.

One of the keys to the success of this process is the ability to easily identify loss of production at each step in the operation, which shows up as "No-load and start-up" time. Reducing this "No-load and start-up" 5 time, which is often a direct result of oversize rock, can often be achieved by spending more money on drilling and blasting to reduce oversize. In this new process added cost at the drilling and blasting stage can be compared to downstream increase in production with a 10 lowering of overall operating cost.

At quarries and mines blasted rock is the first step in the production process. The input data used by the apparatus of the present invention begins with power 15 consumption readings from the primary crusher (Figure 15). If a rock breaker is used to break up oversize at the primary then a pressure transducer operating off this motor can also be monitored to show power consumed and possible down time at this stage. The use of the pressure 20 transducer will help to separate time waiting for trucks to dump at the crusher versus time used to break up oversize rock with the hydraulic breaker.

After the primary crusher all major conveyor motors 25 operating belts at each stage in processing are then monitored with the apparatus of the present invention. If belt scales are installed, these readings, if available as digital readings, can be used as an alternate source; however it is important belt scales are zero checked each 30 day to insure consistent readings. All of these readings form the basis of this new process to measure productivity and will also provide a new simplified method to compare blasting fragmentation results from similar blasts.

Each blast is monitored showing the total energy, above a No-load level used to crush rock at the Primary crusher, Figure 14 and 15. Moving downstream all main  
5 conveyors moving crushed or screened rock are monitored for daily production rates and total tonnage produced for each final rock product size. At each conveyor we also have energy consumption figures in average kilowatts used during a recording period to compare with tonnage rates,  
10 figure 10.

There are many variables which influence the overall production process. The measurements we are taking will provide clear indications of trends and will generate  
15 repeatable and accurate results. For the conveyors and the primary crusher the zeroing function used with power transducers will filter out most outside variables, which may otherwise distort readings. With use, other variables will be identified, and ways can then be established to  
20 filter out or include this new data to better refine the overall process.

Using tonnage production rates and power consumption rates in kilowatts at crushers will provide a new way to  
25 compare blasting results and show the impact on the full process when changes are made at the drilling and blasting stage. At many operations today the drilling and blasting stage is often under pressure to reduce costs, as are other parts of the operation. Drilling and  
30 blasting is one of the easiest areas to measure costs and lowering cost at this stage often results in larger fragmentation where productivity is much more difficult to measure. The apparatus of the present invention will help to insure any changes occurring in one area can be

easily measured throughout the production process to confirm if an overall improvement has been achieved. With continual improvements by industry, with new products for blasting and new equipment for crushing and screening it  
5 is important to be able to evaluate the impact of these new products or equipment on the existing production process. The multi functional apparatus of the present invention will insure all areas of the plant work at optimal levels and any benefits from new products or  
10 equipment will be measurable to see their impact on the production cycle.

This system becomes a useful tool to help operators to see their live production rates (tonnage/hour), daily  
15 production in tonnes (tons) and the motor monitoring function will provide early warning of possible overload conditions. In Mines and Quarries, the combined production and energy consumption figures become a new method to compare blasting results. For the manager this  
20 process can be used to determine maximum production rates at each stage in the process. For planning purposes the apparatus of the present invention can be used to establish the time and tonnes (tons) of blasted rock required to produce a future order for a specific stone  
25 size. Similarly a breakdown of other product sizes produced will be shown to help management decide the best split of products to produce, which will bring the highest margin.

30 The apparatus and process of the present invention is a new process using advanced computer automation control devices to collect and analyze data but keep output data in a format that is easy to read and interpret. The overall process can be further expanded

to include additional input data such as loader and truck scale readings. This additional information may be useful in comparing blasting results but still needs further research. The main purpose of this present process is to  
5 help industry to better understand the overall process and help integrate all operations to optimize overall productivity.

In some circumstances it has been found that the No-  
10 load reading from motors may vary from one day to the next when the motor is oversized for the application, and as a result the No-load reading can move up or down. If the No-load changes, then this change will continue to cause the same shift as load is applied to the conveyor  
15 or crusher. What happens is the slope of the graph shifts depending on the difference in readings. This can introduce an error with the calculated tonnage conversion rates.

20 To adjust for this, it is preferred that the No-Load is actually measured daily and if there is a small change in No-load then the difference in readings can be included in the regression formula that was developed for the conveyor. The end result is a more accurate  
25 tonnage figure for the day. This same principle will help to keep this device on track during cold weather operations which was identified last winter during low temperature testing with a temperature sensor.

30 The key components of the spread sheet, Figure 13b to convert kilowatts to tonnage are as follows: cell E4 is the No-Load reading in kilowatts to operate the conveyor or crusher empty with no material movement. This figure should be checked daily after warm up, to verify

there is no change. The actual check can be made by taking readings for at least 2 cycle times of the conveyor or typically for 2-5 minutes as shown by readings in column H and I. From these readings we need

5 to calculate the average and the standard deviation. The actual No-load reading will be 1.5 to 2.0 Standard deviations above the average. This reading is then compared to the original No-Load taken during the initial calibration for this conveyor. If there is a difference,

10 | (Cell I9), then this difference is applied to the original calibration formula to give a new calibration formula (cell G11).

2. Cell E5 is the peak load for a conveyor or crusher and represents a full load reading under normal full load

15 conditions. If a crusher or conveyor is re-started under full load then a momentary peak may occur which will be capped out at this level to avoid additional kilowatts being added to our conversion to tonnage.

3. Cell C8 is the total operating time, which is

20 converted to total production time cell E8 by subtracting the No-Load time, cell E6.

4. Cell E9 is the average kilowatt reading for the day.

5. Cell E10 is the converted daily kilowatt reading to tonnage using the regression formula for the conveyor

25 based on actual weighed quantities of material over the conveyor for measured periods of time. This formula can be adjusted as shown in cell G11 by taking into account any changes in No-Load. This adjustment will automatically correct for any mechanical changes that

30 might occur with the crusher or conveyor or any major temperature changes as we move from warm to cold operating conditions. It is important that this No-Load test be carried out only after a minimum 30 minutes of

operation to insure that the crusher or conveyor has reached normal operating conditions.

6. Cell E12 is an actual conveyor belt scale reading, which can be used, to compare with the readings being  
5 generated by Glowe-Tech Tonnage Analyzer.

7. Column E is the actual readings in kilowatts with any readings below the No-Load deleted.

8. Column F is the actual converted kilowatt readings to tonnage and are the tonnes per hour reading for  
10 material moving over the conveyor.

9. Column G is the tonnes/hour converted to a totalized tonnage by dividing by the sampling rate, ie, 450 or every 8 seconds. On an Automat version the sampling rate can be increased to every second.

15 10. Cell G13 is the total of all the readings in Column G and becomes a cross check of the tonnage figure in Cell E13.

11. Column G, Calibration formulas illustrates the changes in tonnage using several formulas based on  
20 several sets of material tests conducted on this conveyor. The actual formula being used is the June 20, 2003 version or formula 3, which is being adjusted if there are any changes in the No-Load. It is important to note that if we do not adjust for the changes in No-Load  
25 then increased errors in converted tonnage as high as 25% have been measured especially if mechanical changes occur on a conveyor such as bearing failure of a head pulley. If a significant change in No-Load is detected this can become an early warning of a potential failure of the  
30 equipment.

Note cells highlighted in RED are cells that are adjusted by the length of data collected in columns A and B.

An example of a typical conveyor graph showing several no-load readings and loaded readings ie readings around 7.4 are the conveyor running empty is shown in Figure 13d. When the No-Load readings move up to over 5 12.0 there is dirt jamming by the counter weight on the return side of the conveyor. This graph shows a rising in No-load readings after 3:20pm. This resulted in a major rise in No-load readings which if left unadjusted would have resulted in a reading over 1000 tonnes of extra 10 tonnage for the day. The first spread sheet Figure 13b shows the early part of the day with normal operating conditions and a No-load reading of 7.403 which was 0.103 higher than the original no-load reading taken during the day the conveyor has calibrated. The 1001 tonne over run, 15 occurs if the no-load remains at 7.403. However if new no-load readings taken during the higher no-load period are used to re-adjust the calibration formula, Figure 13f, then the calculated reading is similar to the original belt scale reading. This conveyor has a 20 Milltronics BW100 belt scale so the 2 systems can be compared daily. The apparatus of the present invention gave results within 0-2% of the belt scale when a zero test adjustment was carried out daily for about 2 minutes normally around 12:00 noon. It was also found that the 25 no-load moves up and down daily with small adjustments of 0.15 to 0.30 typically occurring. It is important to do a no-load test the same day a calibration tests is run with material tests so the new readings can be adjusted to the original by the difference in no-load readings. If a 2nd 30 set of tests are done with a no-load +0.15 kwatts higher than the original calibration run, then the actual readings for a given material test would be lowered by - 0.15 kwatts. If the No-load were actually lower, then the test results would be increased. By doing this it has

been found that the data points become more linear. The graph in Figure 13c is a typical calibration graph for the conveyor.

5       Figures 18, illustrates a versions on how to use  
this new technology to present data in a quarry using an  
existing Automat program. This is accomplished by simply  
adding the results of the application of the present  
invention to the Automat program using the OPC server  
10      program which is normally included with most Automat  
programs. This method makes the installation very quick.  
By using the Automat program it becomes easy to use all  
the graphing and report features that are included in the  
Automat program. As seen in Figure 18 the user gets to  
15      see the tonnes per hour of material moving over the  
conveyor, the total tonnes for the day accumulated and  
the total tonnes since the beginning of the year. In  
addition to the reviewed data all data is also presented  
graphically. All of this information comes from the kwatt  
20      readings taken every second which are then checked that  
they are above the No-load reading, then converted to  
tonnage by the calibration formula. The number is divided  
by 3600 to get a tph reading and totalized. The time is  
also stored so each reading above No-load is stored as  
25      production time and all readings at No-load or lower are  
stored as No-Load time or non production time.

The second page from the Automat program shown in  
Figure 19 is the Zero test page which allows the operator  
30      to do an automatic Zero test to check the No-Load reading  
of the conveyor or crusher. This test can be set up  
within the Automat program to be automatically run each  
day at a specific time such as noon hour. This test can  
only be activated once the conveyor is running empty and

then runs for 200 seconds or approximately 2 cycles of the conveyor. At the end of the test all readings are averaged and 1.5 standard deviations are added to the average to give a new mathematical No-load reading

5 equivalent to about 90% of the peak readings taken during a typical test. The new No-load figure is displayed and if there is a change compared to the original No-load reading set at the time the original calibration tests were run, then the difference in No-load reading is

10 applied to the calibration formula derived from a regression calculation. If the No load is higher then the difference is taken off the regression formula and if lower the difference is added to the formula. An example is as follows; the regression formula is tonnes

15  $=30.385 * \text{kwatts} - 149.62 (\text{difference in No-Load} * 30.385)$ ' where 30.385 is parameter 1 and 149.62 is parameter 2 from the standard regression formula from a graph of a line through a series of points, Figure 13c. This revised formula helps to improve accuracy and overcomes

20 many variables that could otherwise distort readings such as changes in temperature, increased friction due to failing idler sets or even bearing failures, windy conditions versus no wind etc.

25 The 3rd page shown in Figure 20 is the material test or calibration test page where all data during a test of loaded material on a conveyor is recorded. Material that has been weighed is loaded on the conveyor or material after it has passed over the conveyor is weighed at a

30 truck scale. With this page the kwatt readings are secured and an average of these readings while a measured quantity of material is moved by the conveyor is calculated. The test is repeated with the material fed at different rates to get 3 or more points on the graph to

run a line through the points and get the regression formula for these points, figure 13c. It is desirable to also run a No-load test either just before or just after these tests to establish the base No-load reading from 5 which all other test points can be compared and adjusted if taken at a latter date and the No-load shifts a bit. These little adjustments have helped to improve accuracy of conversion to tonnage and standardize procedures to insure repeatable results.

10

Figure 21 illustrates the collection of all data from the watt transducers by an Analog data recorder which is hooked up to a pocket PC (PDA) which records the readings every second, runs the calculations and displays 15 up to 8 channels of data on the same screen. The basic screen shows tph and total tonnes. Figure 22 illustrates a second screen shot that shows time of production and No-load time. No-load tests similar to the Automat program may also be done and calculations 20 readjusted automatically after a No-load test, Figure 23 and 24. There is also a feature to save data and run an average reading during a material test 'MT'. Finally Figure 25 illustrates a typical daily summary table for the production time and tonnage for all channels 25 operating. This setup is very compact yet has the capability to store over 1 month's data on a 64meg memory card for up to 8 channels running at the same time. This is equivalent to 8 belt scale units all of which will be stored in a CEMA 4 case that is 12in x 8in x 6 in deep 30 with a clear plastic cover so the operator can see readings during the day.

Figure 17 illustrates yet another embodiment which uses the ACR data logger as the source readings every 4

seconds. In this embodiment, the main figures such as tph and total tonnes moved as well as production time, No-load time and No-load original reading and the current reading being used since the last Zero test are all shown  
5 live. This embodiment also has the zero-test feature which is activated by the operator by simply touching the zero test key. The red numbering indicates the test has been activated and is terminated by simply touching the Zero test key once again. The new No-Load figure is  
10 displayed and is used in the calibration formula to do the conversion to tonnage. In yet another embodiment, the No-load test reading is applied not only for future readings but also retroactively to all readings taken since the start of the day. This allows the flexibility  
15 to do a Zero test latter in the day and have a choice to apply this figure to future readings or to all readings for the day. The actual computer display can be a standard screen or a Touch Screen Industrial PC such as an Advantech 12.1 inch TPC-1260TEX Touch screen or a BSI  
20 12.1 inch RMS-1120 Touch screen.

The apparatus and methods of the present invention provide for a means of measuring the amount of material being processed or moved in an operation such as a quarrying or mining operation which is inexpensive, simple to setup and operate and to adapt to existing operations. The present invention also provides a means to determine how efficient the operation is running i.e. each step in a quarry, mine or sand and gravel operation  
25 is designed to move a certain quantity of material daily at an hourly rate. At some steps in the operation, downtime may occur and if a record is measured of this downtime or "No-load", then this becomes an area that can  
30 be improved to increase production. Utilizing the present

invention, an operator can adjust the process to run at design production rates with minimum downtime to maximize production. This invention provides the measurement tools at a low cost to achieve this goal. In addition if 5 measurements are made at the conveyors coming off the primary and secondary crushers and at some key conveyors going to final stockpiles then these measurements can be used as a new method to compare blasting results.

10       The invention described herein is based on a new method to calibrate the Glove-Tech Tonnage Analyzer, which increases precision and includes new applications, which will help industry to become more productive.

15       Although various preferred embodiments of the present invention have been described herein in detail, it will be appreciated by those skilled in the art, that variations may be made thereto without departing from the spirit of the invention or the scope of the appended 20 claims.